1. OPERATIONAL PROCEDURES

1.1 GENERAL

The Joint Typhoon Warning Center (JTWC) provides a variety of routine products and services to the organizations within its area of responsibility (AOR) as prescribed by USCINCPACINST 3140.1W. JTWC issues the following products:

1.1.1 SIGNIFICANT TROPICAL WEATHER ADVISORY — Issued daily, or more frequently as needed, to describe all tropical disturbances and their potential for further development during the advisory period. Separate bulletins are issued for the Western Pacific and the Indian Oceans.

1.1.2 TROPICAL CYCLONE FORMATION ALERT — Issued in a specified area when synoptic, satellite, or other germane data indicate development of a significant tropical cyclone is likely within 24 hours.

1.1.3 TROPICAL CYCLONE/ TROPICAL DEPRESSION WARNING — Issued periodically throughout each day to provide forecasts of position, intensity, and wind distribution for tropical cyclones in JTWC's AOR.

1.1.4 PROGNOSTIC REASONING MESSAGE — Issued with warnings for tropical storms, typhoons, and super typhoons in the western North Pacific to discuss the rationale for the content of the specific JTWC warning.

1.1.5 PRODUCT CHANGES — The contents and availability of the above JTWC products are set forth in USCINCPACINST 3140.1W. Changes to USCINCPACINST 3140.1W and JTWC products and services are proposed and discussed at the annual U.S. Pacific Command (PACOM) Tropical Cyclone Conference.

1.2 DATA SOURCES

1.2.1 COMPUTER PRODUCTS — Numerical and statistical guidance are available from the USN Fleet Numerical Meteorology and Oceanography Center (FNMOC) at Monterey, California. FNMOC supplies JTWC with analyses and prognoses from the Navy Operational Global Atmospheric Prediction System (NOGAPS) via NIPRNET communication (refer also to section 1.3.5, TESS(3)). NOGAPS products routinely disseminated to JTWC include: surface pressure and winds, upper-air winds, deep-layer-mean winds, geopotential height and height change, and sea-surface temperature. These products are based on the 00Z and 12Z synoptic times, and atmospheric components are available at all standard levels. These products, along with selected ones from the (U.S.) National Center for Environmental Prediction (NCEP), the European Centre for Medium-Range Weather Forecasts (ECMWF), and the Japanese Meteorological Agency (JMA) are received as electronic files via networked computers, and by computer modem connections on government and commercial telephone lines as a backup method for the network. Additionally, selected computer generated products are received via the PC-Based Weather Facsimile (PCGRAFAX) System.

1.2.2 CONVENTIONAL DATA — These data sets are comprised of land and shipboard surface observations, enroute meteorological observations from commercial and military aircraft (AIREPS) recorded within six hours of synoptic times, and cloud-motion winds derived from satellite data. The conventional data are manually and computer plotted, and manually analyzed in the tropics for the surface/gradient and 200-mb levels. These analyses are prepared twice daily from 00Z and 12Z synoptic data.

1.2.3 SATELLITE RECONNAISSANCE — Meteorological satellite imagery recorded at USAF/USN ground sites and USN ships supply day and night coverage in JTWC's AOR. Interpretation of this satellite data provides tropical cyclone positions and estimates of current and forecast intensities (Dvorak, 1984). The USAF tactical satellite sites and Air Force Global Weather Central (AFGWC) currently receive and analyze Special Sensor Microwave/Imager (SSM/I) data to provide locations of tropical cyclones when the low-level center is obscured by higher clouds, and estimates of 35-kt (18-m/sec) wind radii near tropical cyclones.

Data from satellites — Defense Meteorological Satellite Program (DMSP), National Oceanographic and Atmospheric Administration (NOAA), (Japanese) Geostationary Meteorological Satellite (GMS), and (European Geostationary) Meteorological Satellite (METEOSAT) — provide the foundation for reconnaissance.

Use of satellite reconnaissance is discussed further in section 2.3 Satellite Reconnaissance Summary.

Additionally, scatterometry data from the European Remote Sensing (ERS)-1 satellite also provide valuable insight as to the distribution of low-level winds around tropical cyclones. This year's cover shows a scatterometer pass over Typhoon Orson (19W) from the ERS-1 satellite. When remotely sensed data of this quality became available, JTWC immediately began using it to supplement other available data. Evolution of algorithms and display of scatterometer data has occurred rapidly over the past few years and JTWC has been fortunate to have access to this leading edge technology.

JTWC retrieves scatterometry data on a routine basis from web sites on the NIPRNET/Internet maintained by the Naval Oceanographic Office (NAVOCEANO), the Oceanic Sciences Branch of NOAA, and FNMOC. The scatterometry data available at these sites provide information on tropical cyclone position and low-level winds surrounding a tropical cyclone. Heavy-rain contamination near a tropical cyclone's center limits the usefulness of intensity estimation. In addition to determining positions and wind distribution around tropical cyclones, JTWC also uses scatterometry data to refine the twice daily manual analyses of the surface/gradient-level wind flow and atmospheric structure.

Scatterometry algorithms are discussed further in Chapter 7.

1.2.4 RADAR RECONNAISSANCE — Land-based radar observations are used to position tropical cyclones. Once a well-defined tropical cyclone moves within range of land-based radar sites, radar reports are invaluable for determination of position, movement, and, in the case of Doppler radar, storm structure and wind information. JTWC's use of radar reports during 1996 is discussed in section 2.4 Radar Reconnaissance Summary.

1.2.5 AIRCRAFT RECONNAISSANCE — Until the summer of 1987, dedicated aircraft reconnaissance was used routinely to locate and determine the wind structure of tropical cyclones. Now, aircraft fixes are only rarely available from transiting jet aircraft or from weather-reconnaissance aircraft involved in research missions. No aircraft fixes were available in 1996.

1.2.6 DRIFTING METEOROLOGICAL BUOYS — In 1989, the Commander, Naval Meteorology and Oceanography Command (COMNAVMETOCCOM) put the Integrated Drifting Buoy Plan into action to meet

USCINCPACFLT requirements that included tropical cyclone warning support. In 1996, 30 drifting buoys were deployed in the western North Pacific by a NAVOCEANO-contracted C-130 aircraft. Of the 30 buoys, 24 were Compact Meteorological and Oceanographic Drifters (CMOD) with temperature and pressure sensors and six were Wind Speed and Direction (WSD) with wind speed and direction, temperature and pressure. The buoys were evenly split by type over two deployments — the first in June, followed by the second in September. The purpose of the split deployment was to overlap the expected three-month lifespans of the CMOD buoys in order to provide continuous coverage during the peak of the western North Pacific tropical cyclone season.

1.2.7 AUTOMATED METEOROLOGICAL OBSERVING STATIONS (AMOS) — Through a cooperative effort between COMNAVMETOCCOM, the Department of the Interior, and NOAA/NWS to increase data availability for tropical analysis and forecasting, a network of 20 AMOS stations is being installed in the Micronesian Islands (see Tables 1-1 and 1-2). Previous to this effort, two sites were installed in the Northern Mariana Islands at Saipan and Rota through a joint venture between the Navy and NOAA/NWS. The site at Saipan relocated to Tinian in 1992. Since September of 1991, the capability to transmit data via Service ARGOS and NOAA polar-orbiting satellites has been available as a backup to regular data transmission to the Geostationary Operational Environmental Satellite (GOES) West, and more recently for sites to the west of Guam, to the GMS. Upgrades to existing sites are also being accomplished as opportunities arise to enable access to Service ARGOS. JTWC receives data from all AMOS sites via the AWN under the KWBC bulletin headers SMPW01, SIPW01 and SNPW01 (SXMY10 for Tinian and Rota).

1.3 TELECOMMUNICATIONS

Telecommunications support for the NPMOCW/JTWC is provided by the Naval ComputerTelecommunications Area Master Station, Western Pacific (NTWP) and their Base Communications Department. The NPMOCW/JTWC telecommunications link to NTWP is a new fiber-optic cable which incorporates stand-by redundancy features. Connectivity includes "switched" secure and non-secure voice, facsimile, data services, and dedicated audio and digital circuits to NTWP. Telecommunications connectivity and the basic system configurations which are available to JTWC follow.

1.3.1 AUTOMATED DIGITAL NETWORK (AUTODIN) — AUTODIN currently supports the message requirements for JTWC, with the process of converting to the new Defense Messaging System (DMS) in progress. A personal computer (PC) system running the "Gateguard" software application provides transmit and receive message capabilities. Secure connectivity is provided by a dial-up Secure Telephone Unit-III path with NTWP.

The Gateguard system is used to access the AUTODIN/DMS network for dissemination of warnings, alerts, related bulletins, and messages to Department of Defense (DoD) and U.S. Government installations. Message recipients can retransmit these messages for further dissemination using the Navy Fleet Broadcasts, Coast Guard continuous wave (CW) Morse code, and text to voice broadcasts.

AUTODIN/DMS messages are also relayed via commercial telecommunications routes for delivery to non-DoD users. Inbound message traffic for JTWC is received via AUTODIN/DMS addressed to NAVPACMETOCCEN WEST GU/JTWC.

Table 1-1 AUTOMATED METEOROLOGICAL OBSERVING STATIONS SUMMARY

Site	Location		Call sign	ID#	System	Installed
Saipan*	15.2°N	145.7°E	15D151D2	-----	ARC	1986
Rota	14.2°N	145.2°E	15D16448	91221	ARC	1987
Faraulep**	8.1°N	144.6°E	FARP2	52005	C-MAN/ARGOS	1988
Enewetak	11.4°N	162.3°E	ENIP2	91251	C-MAN/ARGOS	1989
Ujae***	8.9°N	165.7°E	UJAP2	91365	C-MAN	1989
Pagan	18.1°N	145.8°E	PAGP2	91222	C-MAN/ARGOS	1990
Kosrae	5.4°N	163.0°E	KOSP2	91355	C-MAN/ARGOS	1990
Mili	6.1°N	172.1°E	MILP2	91377	C-MAN	1990
Oroluk	7.6°N	155.2°E	ORKP2	91343	C-MAN	1991
Pingelap	6.2°N	160.7°E	PIGP2	91352	C-MAN/ARGOS	1991
Ulul	8.4°N	149.4°E	NA	91328	C-MAN/ARGOS	1992
Tinian*	15.0°N	145.6°E	15D151D2	91231	ARC	1992
Satawan	6.1°N	153.8°E	SATP2	91338	C-MAN/ARGOS	1993
Ulithi	9.9°N	139.7°E	NA	91204	C-MAN/ARGOS	1995
Ngulu	8.3°N	137.5°E	NA	91411	C-MAN/ARGOS	1995
Ebon	4.6°N	168.7°E	NA	91442	C-MAN/ARGOS	1996
Maloelap	8.7°N	171.2°E	NA	91374	C-MAN/ARGOS	1996

* Saipan site relocated to Tinian and commissioned on 1 June 1992.
** The prototype site on Faraulep was destroyed on 28 November 1991 by Super Typhoon Owen.
*** Ujae site was destroyed on 18 November 1992 by Super Typhoon Gay.

ARC = Automated Remote Collection system (via GOES West)
C-MAN = Coastal-Marine Automated Network (via GOES West or GMS)
ARGOS = Service ARGOS data collection (via NOAA's TIROS-N)

Table 1-2 PROPOSED AUTOMATED METEOROLOGICAL OBSERVING STATIONS

Site	Location		Installation	Delayed
Pulusuk	6.5°N	149.5°E	1993	Yes*
Faraulep	8.6°N	144.6°E	1994	Yes
Eauripik	6.7°N	143.0°E	1994	Yes
Utirik	11.2°N	169.7°E	1994	Yes
Satawal	7.4°N	147.0°E	1995	Yes
Ujelang	9.8°N	161.0°E	1995	Yes
Maug	20.0°N	145.2°E	1996	Yes

* Runway construction

1.3.2 AUTOMATED WEATHER NETWORK (AWN) — The AWN provides weather data over the Pacific Meteorological Data System (PACMEDS). JTWC uses two PC systems which run the Windows based WINDS/AWNCOM software application package to interface with a dedicated 1.2 kb/sec (kilo-bits per second) PACMEDS circuit. These PC systems provide JTWC the PACMEDS transmit and receive capabilities needed to effectively store and manipulate large volumes of alphanumeric meteorological data available from reporting stations throughout JTWC's AOR. The AWN also allows JTWC access to data which are available on the Global Telecommunications System (GTS). JTWC's AWN station identifier is PGTW.

1.3.3 AUTOMATED WEATHER DISTRIBUTION SYSTEM (AWDS) — The AWDS consists of two dual-monitor workstations which communicate with a UNIX based communications/data server via a private Local Area Network (LAN). The server's data connectivity is provided by two dedicated long-haul data circuits. The AWDS provides JTWC with additional transmit and receive access to alphanumeric AWN data at Tinker AFB using a dedicated 9.6 kb/sec circuit. Access to satellite imagery and computer graphics from Air Force Global Weather Center (AFGWC) is provided by another dedicated 9.6 kb/sec circuit.

AWDS current configuration was upgraded in 1996 to include improved workstation performance, and integration into NPMOCW's LAN backbone which has access to the Defense Information Systems Network's (DISN), this and the NIPRNET connectivity should allow JTWC to send and receive products among other AWDS systems. Send e-mail requests to jtops@npmocw.navy.mil for more information.

1.3.4 DEFENSE SWITCHED NETWORK (DSN) — DSN is a worldwide, general purpose, switched telecommunications network for the DoD. The network provides a rapid and vital voice and data link for JTWC to communicate tropical cyclone information with DoD installations and civilian agencies.

JTWC utilizes DSN to access DSN-based users, FTS2000, SprintNET networks for commercial or non-DoD based users, and local commercial long distance carriers for voice and data requirements.

The DSN and commercial telephone numbers for JTWC are 349-5240 or 349-4224. The commercial area code is 671 and the DSN Pacific area code is 315.

1.3.5 TACTICAL ENVIRONMENTAL SUPPORT SYSTEM (3) (TESS(3)) — The TESS(3) is connected by NIPRNET to FNMOC. NIPRNET connectivity is provided by a dedicated virtual-switched data services 56 kb/sec packet switched-data link. FNMOC's supercomputer generated gridded fields are pushed to the TESS(3) using NIPRNET, allowing for local value added tailoring of analyses and prognoses. The TESS(3) provides connectivity through NIPRNET to all COMNAVMETOCCOM Centers worldwide.

1.3.6 NIPRNET—DISN's NIPRNET has replaced the DDN MILNET computer communications network, providing a much needed boost in throughput speed for the transfer of large data and image files. NIPRNET has links or gateways to the non-DoD Internet, allowing data to be pulled and pushed from Internet based World Wide Web (WWW) and File Transfer Protocol (FTP) servers. This capability has enhanced JTWC's ability to exchange data with the Internet-based research community.

The JTWC's products are currently available to users of the DISN based Secret IP Router Network (SIPRNET) using WWW browser software. The JTWC's SIPRNET web site address can be obtained by contacting JTWC's Operations Officer. The JTWC's unclassified NIPRNET/Internet web site address is http://www.npmocw.navy.mil. The JTWC's Internet e-mail server's IP address is 192.231.128.1 and the e-mail address is jtops@npmocw.navy.mil.

1.3.7 TELEPHONE FACSIMILE— TELEFAX provides the capability to rapidly scan and transmit, or receive, documents over commercial telephone lines or DSN. TELEFAX is used to disseminate tropical cyclone advisories and warnings to key agencies on Guam and, in special situations, to DoD, other U.S. Government agencies, and the other Micronesian Islands. Inbound documents for JTWC are received at 349-6143, 349-6101, or 349-4032 (commercial area code 671, or DSN Pacific area code 315).

1.3.8 LOCAL USER TERMINAL (LUT) — JTWC uses a LUT, provided by the Naval Oceanographic Office, as the primary means of receiving real-time data from drifting meteorological buoys and ARGOS-equipped AMOS via the polar-orbiting TIROS-N satellites.

1.4 DATA DISPLAYS

1.4.1 AUTOMATED TROPICAL CYCLONE FORECAST (ATCF) SYSTEM — The ATCF is an advanced software program that assists the Typhoon Duty Officer (TDO) in the preparation, formatting, and dissemination of JTWC's products. It cuts message preparation time and reduces the number of corrections. The ATCF automatically displays: the working and objective best tracks; forecasts of track, intensity, and wind distribution; and, information from computer generated forecast aids and products from other agencies. It also computes the myriad of statistics calculated by JTWC. Links have been established through the LAN to the NAVPACMETOCCEN WEST Operations watch team to facilitate the generation of tropical cyclone warning graphics for the fleet facsimile broadcasts, for NAVPACMETOCCEN WEST's local metwatch program, and for warning products for Micronesia. A module permits satellite reconnaissance fixes to be input from 36 OSS/OSJ into the LAN.

1.4.2 TESS(3) receives, processes, stores, displays and prints copies of FNMOC data and environmental products. It also ingests and displays satellite imagery from the Naval Meteorological Data Receiver-Recorder Set (SMQ-11) and other TESS(3) sets worldwide.

1.4.3 AWDS functions are similar to those of the TESS(3), but the environmental products and satellite global data base imagery are produced by AFGWC.

1.4.4 NAVAL OCEANOGRAPHIC DATA DISTRIBUTION SYSTEM (NODDS) — NODDS is a personal computer (PC)-based system that uses a telephone modem to download, store and display environmental and satellite products from FNMOC.

1.4.5 NAVAL SATELLITE DISPLAY SYSTEM - GEOSTATIONARY (NSDS-G) — The NSDS-G is NAVPACMETOCCEN WEST's primary geostationary imagery processing and display system. It can be used to process high resolution geostationary imagery for analysis of tropical cyclone positions and intensity estimates for the Western Pacific Ocean should the Meteorological Imagery, Data Display, and Analysis System (MIDDAS - see Chapter 2) and Mark IVB (see Chapter 2 also) fail.

1.4.6 PC-BASED WEATHER FACSIMILE (PCGRAFAX) SYSTEM — PCGRAFAX is a microcomputer-based system that receives, stores and displays analog and digital facsimile products that are transmitted over high frequency (HF) radio.

1.4.7 SATELLITE WEATHER DATA IMAGING SYSTEM (SWDIS) — The SWDIS (also known as the M-1000) is a PC-based system that interfaces with the LAN to retrieve, store, and display various products such as: geostationary-satellite imagery from other NSDS-G sites at Rota (Spain), Pearl Harbor (Hawaii), or Norfolk (Virginia), scatterometer data from NAVOCEANO and NOAA, and composites of global geostationary-satellite imagery from the Internet. The SWDIS has proven instrumental in providing METEOSAT reduced-resolution coverage of tropical cyclones over the western Indian Ocean as well as long time-series animations of water-vapor imagery.

1.5 ANALYSES

The JTWC TDO routinely performs manual streamline analyses of composite surface/gradient-level (3000 ft (914 m)) and upper-tropospheric (centered on the 200-mb level) data for 00Z and 12Z daily. Computer analyses of the surface, 925-, 850-, 700-, 500-, 400-, and 200-mb levels, deep-layer-mean winds, frontal boundaries depiction, 1000-200 mb/400-200 mb/and 700-400 mb wind shear, 500-mb and 700-mb 24-hour height change, and a variety of other meteorological displays come from the 00Z and 12Z FNMOC data bases. Additional sectional charts at intermediate synoptic times and auxiliary charts, such as station-time plot diagrams, time-height cross-section charts and pressure-change charts, are analyzed during periods of significant tropical cyclone activity.

1.6 FORECAST PROCEDURES

This section first introduces the Systematic and Integrated Approach to TC Track Forecasting by Carr and Elsberry (1994), referred to hereafter as the "Systematic Approach" and then provides JTWC's basic approach to track, intensity and wind radii forecasting.

1.6.1 THE SYSTEMATIC APPROACH — JTWC began applying the Systematic Approach (Figure 1.1) in 1994. The basic premise of this approach is that forecasters can improve upon dynamical track forecasts generated by numerical models and other objective guidance if the forecasters are equipped with:

1) a meteorological knowledge base of conceptual models that organizes a wide array of scenarios into a relatively few recurring, dynamically-related situations; and

2) a knowledge base of numerical-model TC-forecast traits and objective-aid traits within the different recurring situations that is organized around the meteorological knowledge base.

1.6.1.1 General Concepts — *Track, intensity, and size components of a TC forecast are dynamically interdependent.*

1) TC motion affects intensity and how a TC intensifies can affect its motion.

2) TC size affects propagation relative to environmental steering. A large TC may significantly modify its environment. Thus, the present size of a TC and any subsequent changes in size can affect motion.

3) TC size may affect intensity indirectly through changes induced on TC motion.

1.6.1.2 Key Motion Concepts — *TC motion results from a variety of causes.*

1) Environmental Steering — To a first approximation, TC's go where the winds of

the large scale environment blow them (i.e., TCs are a "cork in the stream").

2) TC Propagation — The motion of TCs usually departs in a minor, but not insignificant way from the steering provided by the large scale environment.

3) TC-Environment Interaction — In certain situations, the circulation of the TC interacts with the environment in such a way as to significantly alter the structure of the environment, thus modifying the environmental steering winds which are a primary source of TC motion.

1.6.1.3 Knowledge Base Framework

1.6.1.3.1 Environment Structure — Structure is classified in terms of a large-scale synoptic PATTERN and two or more synoptic REGIONs within the pattern that tend to produce characteristic directions and speeds of steering flow for a TC located therein. Four patterns with six associated regions are recognized by the Systematic Approach. JTWC notes that not all tropical cyclones fit "neatly" into these patterns/regions at all times and that hybrids and transitions between patterns occur. These patterns/regions are briefly described below.

1.6.1.3.1.1 Patterns — There are four primary patterns:

Standard Pattern (S) (Figure 1.2)

1) most frequently occurring pattern in the WNP; and,

2) key feature is roughly zonally-oriented subtropical ridge (STR) anticyclones.

Poleward-Oriented Pattern (P) (Figure 1.3)

1) second highest frequency of occurrence in the WNP;

2) key feature is a ridge (anticyclone) that extends from the STR deep into the tropics and interrupts the tropical easterlies;

3) usually has SW-to-NE axis orientation; and,

4) usually produces strong poleward steering on its west and poleward side.

Monsoon Gyre (G) (Figure 1.4)

1) only occurs during June-November period;

2) key feature is a particularly large and deep monsoonal circulation (thus, "monsoon

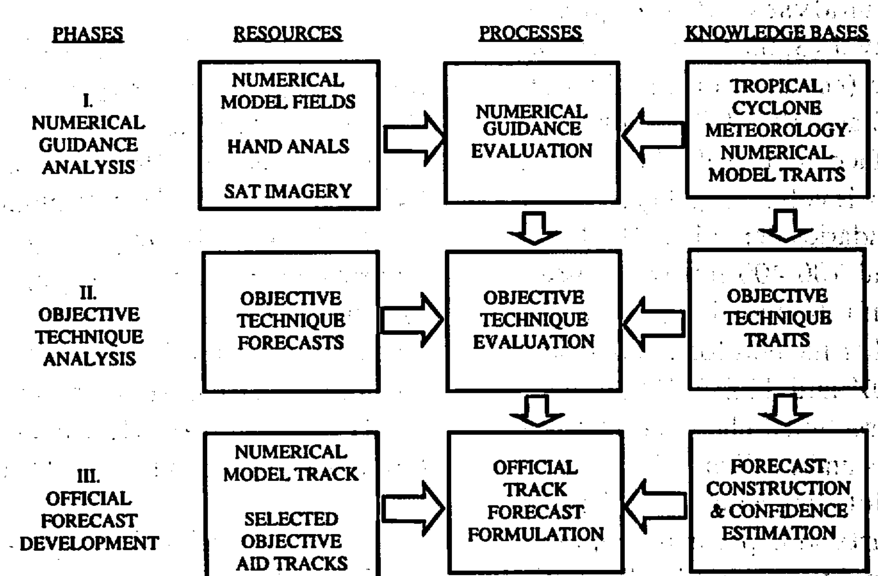

Figure 1.1 Systematic Approach Flowchart

gyre"); and,

3) usually situated between a zonally-oriented STR anticyclone to the NW and a meridionally-oriented anticyclone on its eastern periphery.

Multiple TC (M) (Figure 1.5)

1) key feature is more than one TC with a large break in the STR in the vicinity of the two TCs;

2) the TCs are oriented approximately east-west (i.e., zonally-oriented TCs);

3) the TCs must be far enough apart to preclude significant mutual advection, but close enough to preclude the development of ridging between them (typically greater than 10°, but less than about 25°);

4) the average latitude of the two TCs must be sufficiently close to the latitude of the STR axis (no more than about 10° equatorward or 5° poleward) so that regions of poleward/equatorward flow are established, which affect TC motion and intensification; and,

5) there are three subsets of the "M" pattern which describe varying degrees of interaction between the two cyclones.

1.6.1.3.1.2 Regions. There are six primary regions associated with the four patterns:

Dominant Subtropical Ridge (DR) — the area of tropical easterlies equatorward of the STR axis, except near any break in the STR;

Weakened Subtropical Ridge (WR) — the area of weaker southeasterly winds in the vicinity of a break in the STR;

Accelerating Midlatitude Westerlies (AW) — the area of eastward and poleward steering extending east from a break in the STR;

Poleward Oriented (PO) - the area of poleward steering west of the ridge feature in the "P" and "G" Patterns;

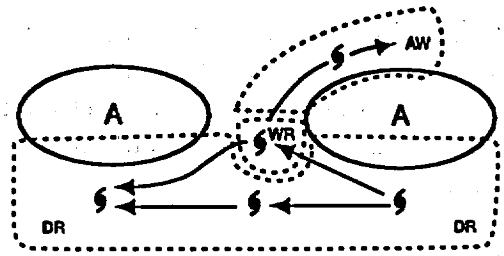

Figure 1.2 Standard Pattern

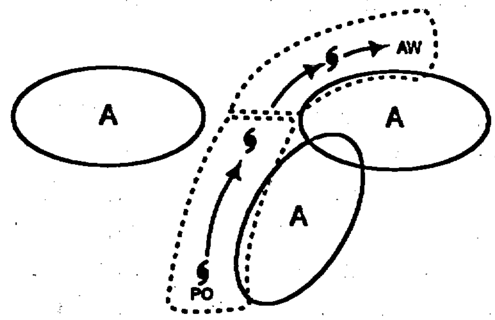

Figure 1.3 Poleward Oriented Pattern

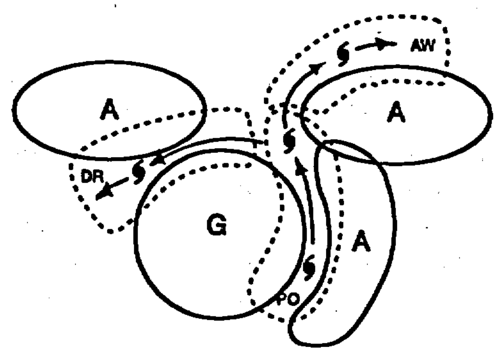

Figure 1.4 Gyre Pattern

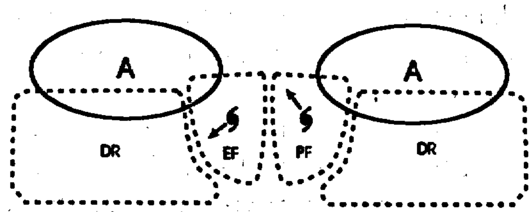

Figure 1.5 Multiple TC Pattern

LEGEND FOR FIGURES:

→ = CHARACTERISTIC TC TRACK
-- = REGIONAL BOUNDARY
DR = DOMINANT RIDGE
A = ANTICYCLONE
AW = ACCELERATING WESTERLIES
G = GYRE
WR = WEAKENED RIDGE
EF = EQUATORIAL FLOW
PF = POLEWARD FLOW
PO = POLEWARD ORIENTED

Multiple TC Poleward Flow (PF) — created in the region of the eastern TC of a "M" Pattern as a result of the gradient between the western TC and the STR circulation to the east; and,

Multiple TC Equatorward Flow (EF) — created in the region of the western TC of a "M" Pattern as a result of the gradient between the eastern TC and the STR circulation to the west.

1.6.1.3.1.3 Nomenclature. — JTWC makes routine use of the aforementioned Patterns and Regions of the Systematic Approach. In order to quickly transcribe this information, a shorthand contraction standard has developed. By utilizing the one-letter contraction of a pattern and the two-letter contraction of an associated region (e.g., S/DR) an effective method of quickly and accurately describing Systematic Approach concepts in writing exists.

1.6.1.3.2 TC Structure. — TC structure consists of an INTENSITY that is based on the maximum wind speed near the center of the TC, and a SIZE that is based on some measure of the extent of the TC windfield. TC intensity is related to steering level and TC size is related to propagation and environment modification.

1.6.1.3.3 Transitional Mechanism. — These mechanisms act to change the structure of the environment (pattern/region) and fall into two categories:

1) TC-Environment Transformations. The TC and the environment may interact, resulting in a change in environmental structure (pattern/region) and thus the direction/speed of the associated steering flow. In addition, TC-environment transformations may result in a change to TC structure. Recognized TC-environment transformations are listed below (refer to Carr and Elsberry (1994) for a more thorough treatment):

- *Beta Effect Propagation*
- *Vertical Wind Shear*
- *Ridge Modification by TC*
- *Monsoon Gyre - TC Interaction*
- *TC Interaction (Direct (DTI), Semi-direct (STI), and Indirect (ITI)) (Figure 1.6)*

2) Environmental Effects. These also result in changes to the structure of the environment (pattern/region) surrounding the TC, but do not depend on, are or largely independent of, the presence of the TC. Recognized environmental effects are listed below (refer to Carr and Elsberry (1994) for thorough treatment):

- *Advection by Environment*
- *Monsoon Gyre Formation*
- *Monsoon Gyre Dissipation*
- *Subtropical Ridge Modulation (by mid-latitude troughs)*

TC movement, intensification, and size evolution are closely linked, therefore, an "ideal TC forecast approach" may be defined as a fully integrated solution for the time evolution of the 3-dimensional TC circulation. TC track, intensity and size forecasts are then to be considered as three partial representations of the total forecast solution.

1.6.2 BASIC APPROACH TO FORECASTING

1.6.2.1 Initial Positioning — The warning position is the best estimate of the center of the surface circulation at synoptic time. It is estimated from an analysis of all fix information received from one hour before to one and one-half hours after that synoptic time. The analysis is aided by a computer-generated objective best-track scheme that weights fix information based on its statistical accuracy. The TDO includes synoptic observations and other information to adjust the position, testing consistency with the past direction, speed of movement and the influence of the different scales of motions. If the fix data are not

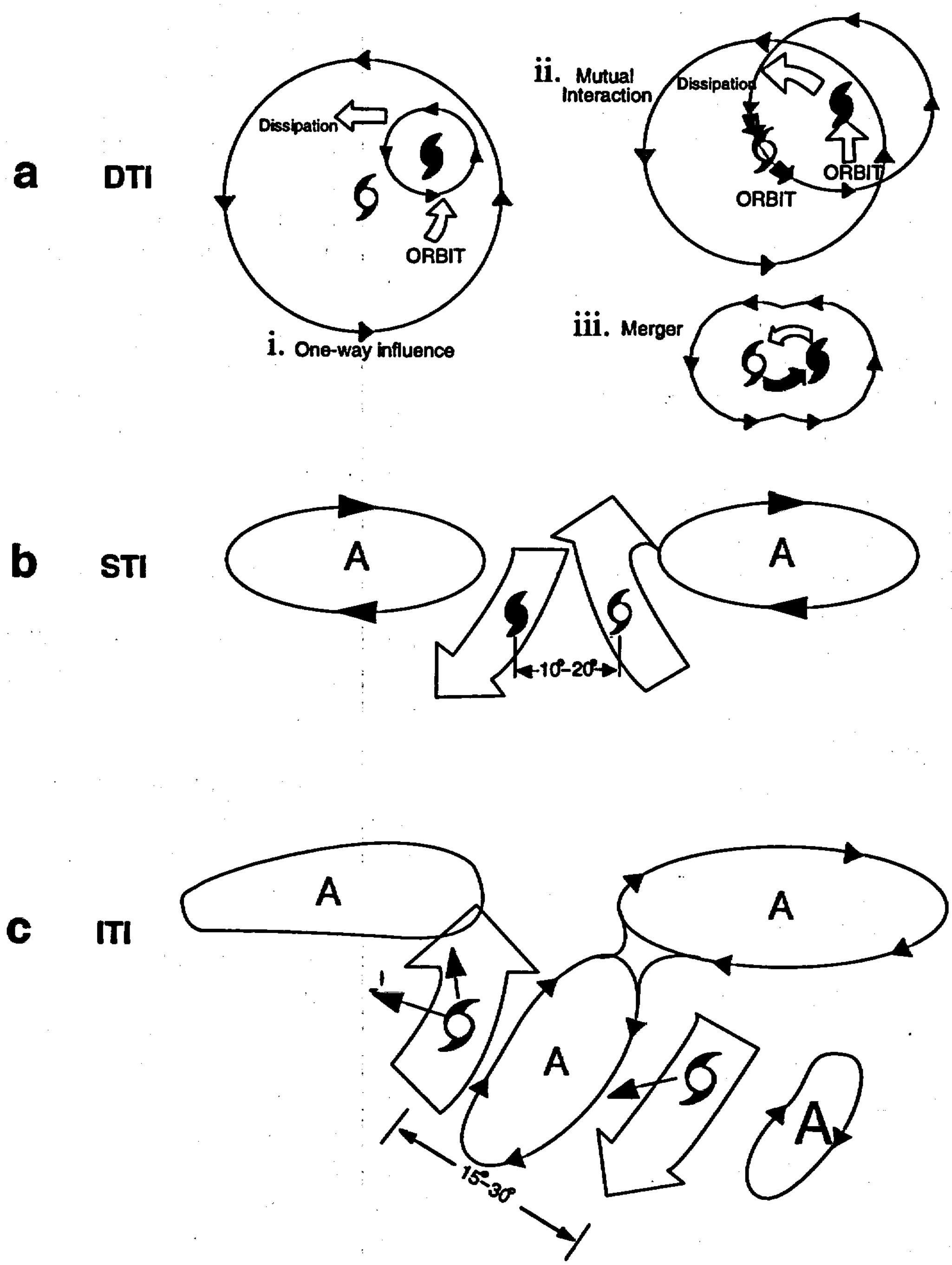

Figure 1-6 Tropical Cyclone Interaction: (a) Direct TC Interaction (DTI) is composed of three types — (i) one-way influence, (ii) mutual interaction, and (iii) merger — (b) Semi-Direct TC Interaction (STI), (c) and Indirect TC Interaction (ITI).

available due to reconnaissance-platform malfunction or communication problems, or are considered unrepresentative, synoptic data and/or extrapolation from previous fixes are used.

1.6.2.2 Track Forecasting — In preparing the JTWC official forecast, the TDO evaluates a wide variety of information and employs Systematic Approach methodology. The JTWC uses a standardized, three-phase tropical cyclone motion-forecasting process to improve forecast accuracy and forecast-to-forecast consistency. Figure 1.1 depicts the three phases and inputs to the Systematic Approach outlined below.

1.6.2.2.1 Numerical Guidance Analysis Phase — NOGAPS analyses and prognoses at various levels are evaluated for position, development, and movement of not only the tropical cyclone, but also relevant synoptic features such as:

1) subtropical ridge circulations;

2) midlatitude short/long-wave troughs and associated weaknesses in the subtropical ridge;

3) monsoon surges;

4) influences of cyclonic cells in the tropical upper-tropospheric trough (TUTT);

5) other tropical cyclones; and,

6) the distribution of sea-surface temperature.

The TDO determines into which pattern/region the tropical cyclone falls, and what environmental influences and transitional mechanisms are indicated in the model fields. The process outlined above permits the TDO to develop an initial impression of the environmental steering influences to which the tropical cyclone is, and will be, subjected to as depicted by NOGAPS. The NOGAPS analyses are then compared to the manually-plotted and analyzed charts prepared by the TDA and TDO, and to the latest satellite imagery, in order to determine how well the NOGAPS-initialization process has conformed to the available synoptic data, and how well the resultant analysis fields agree with the synoptic situation inferred from the imagery. Finally, the TDO compares both the computer- and manually-analyzed charts to monthly climatology in order to make a preliminary determination of to what degree the tropical cyclone is, and will continue to be, subject to a climatological or nonclimatological synoptic environment. Noting latitudinal and longitudinal displacements of subtropical ridge and long-wave midlatitude features is of particular importance, and will partially determine the relative weights given to climatologically- or dynamically-based objective forecast guidance.

1.6.2.2.2. Objective Techniques Analysis Phase — By applying the guidance of the Systematic Approach, the TDO can relate the latest set of guidance given by JTWC's suite of objective techniques with the NOGAPS model prognoses and currently observed meteorological conditions. Performance characteristics for many of the objective techniques within the synoptic patterns/regions outlined in section 1.6.1.3.1.1 have been determined. Estimating the likely biases of each of the objective technique forecasts of TC track, intensity, and size given the current meteorological situation, the TDO eliminates those which are most likely inappropriate. The TDO also determines the degree to which the current situation is considered to be, and will continue to be, climatological by comparing the forecasts of the climatology-based objective techniques, dynamically-based techniques, and past motion of the present storm. Additionally, the spread of the set of objective forecasts, when plotted, is used to provide a measure of the predictability of subsequent motion, and the advisability of including a moderate-probability alternate forecast scenario in the prognostic reasoning message or warning (outside the western North Pacific).

The directional spread of the plotted objective techniques is typically small well before or well after recurvature (providing high forecast confidence), and is typically large near the decision point of recurvature or non-recurvature, or during a quasi-stationary or erratic-movement phase. A large spread increases the likelihood of alternate forecast scenarios.

1.6.2.2.3. Forecast Development Phase — The TDO then constructs the JTWC official forecast giving due consideration to:

1) interpretation of the TC-environment scenario depicted by numerical model guidance;

2) known properties of individual objective techniques given the present synoptic situation or geographic location;

3) the extent to which the synoptic situation is, and is expected to remain, climatological; and,

4) past statistical performance of the various objective techniques on the current storm.

The following guidance for weighting the objective techniques is applied:

1) weight persistence strongly in the first 12 to 24 hours of the forecast period;

2) use conceptual models of recurring, dynamically-related meteorological patterns with the traits of the numerical and objective-aid guidance associated with the specific synoptic situation; and,

3) give significant weight to the last JTWC forecast at all forecast times, unless there is significant evidence to warrant departure (also consider the latest forecasts from regional warning centers, as applicable).

1.6.3 INTENSITY FORECASTING — The empirically derived Dvorak (1984) technique is used as a first guess for the intensity forecast. The TDO then adjusts the forecast after evaluating climatology and the synoptic situation. An interactive conditional-climatology scheme allows the TDO to define a situation similar to the system being forecast in terms of location, time of year, current intensity, and intensity trend. Synoptic influences such as the location of major troughs and ridges, and the position and intensity of the TUTT all play a large part in intensifying or weakening a tropical cyclone. JTWC incorporates a checklist into the intensity-forecast procedure. Such criteria as upper-level outflow patterns, neutral points, sea-surface temperatures, enhanced monsoonal or cross-equatorial flow, and vertical wind shear are evaluated for their tendency to enhance or inhibit normal development, and are incorporated into the intensity-forecast process. In addition to climatology and synoptic influences, the first guess is modified for interactions with land, with other tropical cyclones, and with extratropical features. Climatological and statistical methods are also used to assess the potential for rapid intensification (Mundell, 1990).

1.6.4 WIND-RADII FORECASTING — Since the loss of dedicated aircraft reconnaissance in 1987, JTWC has turned to other data sources for determining the radii of winds around tropical cyclones. The determination of wind-radii forecasts is a three-step process:

1) Low-level satellite drift winds, scatterometer and microwave imager 35-kt wind-speed analysis (see Chapter 2), and synoptic data are used to derive the current wind distribution.

2) The first guess of the radii is then determined from statistically-derived empirical wind-radii models. The JTWC currently uses three models: the Tsui model, the Huntley model, and the Martin-Holland model. The latter model uses satellite-derived parameters to determine the size and shape of the wind profile associated with a particular tropical cyclone. The Martin-Holland model also incorporates latitude and speed of motion to produce an asymmetrical wind distribution. These models provide wind-distribution

analyses and forecasts that are primarily influenced by the intensity forecasts. The analyses are then adjusted based on the actual analysis from step 1), and the forecasts are adjusted appropriately.

3) Finally, synoptic considerations, such as the interaction of the cyclone with mid-latitude high pressure cells, are used to fine-tune the forecast wind radii.

1.6.5 EXTRATROPICAL TRANSITION — When a tropical cyclone moves into the mid-latitudes, it often enters an environment that is detrimental to the maintenance of the tropical cyclone's structure and energy-producing mechanisms. The effects of cooler sea-surface temperatures, cooler and dryer environmental air, and strong vertical wind shear all act to convert the tropical cyclone into an extratropical cyclone. JTWC indicates this conversion process is occurring by stating the tropical cyclone is "becoming extratropical." JTWC will indicate the conversion is expected to be complete by stating the system has become "extratropical." When a tropical cyclone is forecast to become extratropical, JTWC coordinates the transfer of responsibility with NAVPACMETOCCEN WEST which assumes warning responsibility for the extratropical system.

1.6.6 TRANSFER OF WARNING RESPONSIBILITY — JTWC coordinates the transfer of warning responsibility for tropical cyclones entering or exiting its AOR. For tropical cyclones crossing 180°E longitude in the North Pacific Ocean, JTWC coordinates with the Central Pacific Hurricane Center (CPHC), Honolulu via NAVPACMETOCCEN, Pearl Harbor, Hawaii. For tropical cyclones crossing 180°E longitude in the South Pacific Ocean, JTWC coordinates with NAVPACMETOCCEN, which has responsibility for the eastern South Pacific. Whenever a tropical cyclone threatens Guam, files are electronically transferred from JTWC to the Alternate Joint Typhoon Warning Center (AJTWC) collocated with NAVPACMETOCCEN. In the event that JTWC should become incapacitated, the AJTWC assumes JTWC's functions. Assistance in determining satellite reconnaissance requirements, and in obtaining the resultant data, is provided by the weather unit supporting the 15th Air Base Wing, Hickam AFB, Hawaii.